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MORPHOMETRIC AND LAND USE / LAND COVER BASED SUB-WATERSHED PRIORITIZATION OF TOREHALLA USING REMOTE SENSING AND GIS

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ABSTRACT

The quantitative geomorphic studies of a basin is helpful in prioritizing its sub-watersheds. The Watershed prioritization based on land use / land cover analysis is gaining importance in natural resources management. In the present study an attempt has been made to develop and monitor soil and water resources by studying in detail the sub-watersheds. The prioritization is based on morphometric and land use / land cover analysis using remote sensing and GIS technique. The investigation reveals that sub-watersheds SW2 and SW14 are very highly prioritized based on morphometric analysis. The sub-watershed SW8 is ranked under very high category based on land use/land cover analysis. However it is observed that upon integrating both morphometric and land use / land cover thematic layers, three sub-watersheds *Viz.*, SW6, SW9 and SW11 are found to receive common priority by both the approaches and remaining sub-watersheds show little correlation difference.

KEYWORDS: Land Use / Land Cover, Morphometry, Prioritization, Remote Sensing and GIS, Watershed

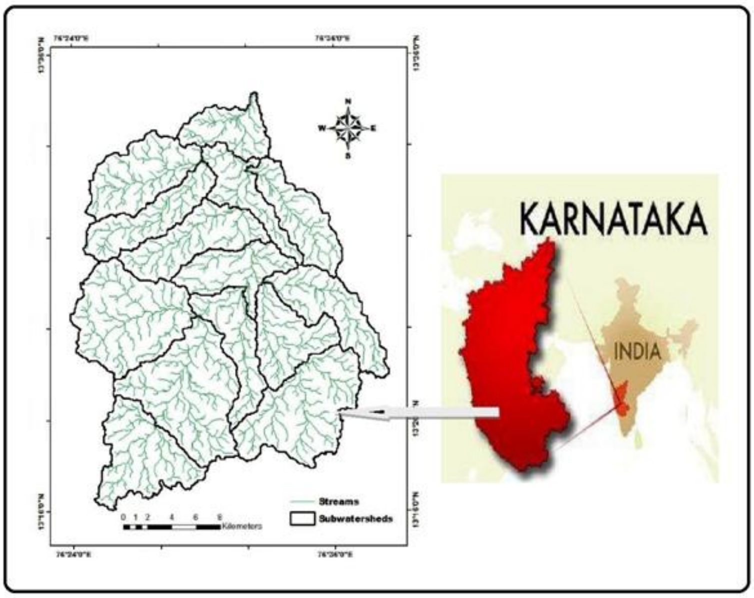
INTRODUCTION

A watershed is an area of land, where all of the water that drains under it goes into the same place. It combines with other watersheds to form a network of streams and rivers that progressively drains into larger water bodies. Watersheds are important as the surface water features and storm water runoff within a watershed ultimately drain to other bodies of water. It is essential to consider these downstream impacts when developing and implementing water management and quality protection/restoration. Management of the environment has been primarily focused on specific issues such as air, land, and water. Watershed management is a continuous process where data has to be collected, analyzed to identify issues and design plans to protect and promote resource sustainability. Thus the watershed level approach in managing of resources, the negative impacts on the system can be identified. Hence there is scope for improvement of resource sustainability for generations to come.

The quantitative morphometry is useful in evaluating the river basins /watersheds. Morphometric parameters are the simple means by which geologic and geomorphic features can be best studied. The role of lithology and geologic structures in the development of stream network can be understood by studying nature, type of drainage pattern and also through quantitative morphometry. Measurement of linear and shape parameters envisages to understand basin morphology and to prioritize sub-watersheds (Biswas et. al., 1999). Advanced techniques like remote sensing and GIS have evolved as a powerful tools in efficient planning and management of watersheds. Land use refers to the economic use to which land is put by man. On the other hand, Land Cover refers to the vegetation, rocky outcrops, or other features that cover the land. Two land parcels may have similar land cover, but different land use. Assessment of land use accurately forms the basis for proper planning, management and monitoring of available natural resources. In the present work an attempt has been made to prioritize the sub- watersheds of Torehalla watershed based on morphometric and land use/land cover analysis making use of remote sensing and GIS techniques.

STUDY AREA

The Torehalla watershed lies between latitude $13^{0}15^{I}$ to $13^{0}34^{I}$ N and longitude $76^{0}18^{I}$ to $76^{0}42^{I}$ E, covering an area of 569 Sq.kms (Map 1). This watershed comprises parts of Tiptur, Chikkanayakanahalli and Huliyar taluks of Tumkur district. The Drainage pattern seen is Dendritic to semi –Dendritic. The main Torehalla channel flows in northerly direction and is Perennial only during monsoon season. The area is made up of plain lands and residual dome shaped hillocks and hill ranges. In general the area forms an undulating topography with sparse vegetation, wide valleys and plains.



Map 1: Location of the Study Area

The highest elevation in the study area is 892m at Buraganahatti peak and lowest is 711m. The main lithology of the watershed are Peninsular Gneiss, Chloritic Schist and Granites. The soils of the study area are Red loamy, red sandy, mixed red and black soils.

METHODOLOGY

The Survey of India (SOI) toposheets 57C/7 and 57C/11 on 1: 50.000scale were registered to UTM projection (WGS 84 North, Zone 43) and the base map is created. The drainage network from ASTER DEM was extracted and sub-watersheds are delineated using the Arc Hydro toolset in ArcGIS 9.2 adopting the standard procedures. The stream ordering was analyzed as per Horton (1945) and Strahler (1964). The base map was overlaid on satellite data and different land use / land cover features were delineated based on basic interpretation keys, spectral signatures, terrain characters and limited field checks. The delineation and thematic map preparation is carried out in GIS environment.

RESULTS AND DISCUSSIONS

The morphometric analysis carried for the present study comprises of 14 sub-watersheds. The drainage pattern is dendritic to semi-dendritic type. The morphometric analysis for the parameters namely stream order, stream length, bifurcation ratio, stream length ratio, basin length, drainage density, stream frequency, elongation ratio, circulatory ratio, form factor etc., have been estimated and discussed below. The parameters are tabulated in Table 1.

Bifurcation Ratio (Rb)

It is the ratio of number of streams of a given order to the number of streams of the next higher order (Schumm, 1956). The ratio varies with the different classifications of stream orders. The lower values of 'Rb' are

characteristics of the sub-watersheds which have less structural disturbances (Strahler, 1964) and the drainage pattern has not been distorted due to the structural disturbances. In the present study the bifurcation values range from 3.2 to 9.7. The 'Rb' values of the sub-watersheds in the study area indicates that they are structural disturbed.

Drainage Density (Dd)

The estimation of drainage density is a useful numerical measure of landscape dissection and runoff potential (Chorley, 1962). On the one hand, the drainage density is a result of interacting factors controlling the surface runoff. But on the other hand, it is influencing the output of water and sediment from a drainage basin. Drainage density expresses the closeness of spacing of channels. The lower values of 'Dd' leads to course drainage texture and a higher value for fine texture (Strahler, 1964). In the present study the 'Dd' values range from 1.3 to 1.5km / km^2. All the sub-watersheds of the study area falls under low to moderate drainage density category indicating high permeable subsoil, good vegetation cover and low relief.

Stream Frequency (Fs)

Stream frequency/channel frequency (Fs) is the total number of stream segments of all orders per unit area (Horton, 1932). The values of 'Fs' in the sub-watersheds varies from 1.26 to 1.59. The low values of 'Fs' indicate that the area is of low relief with permeable subsurface material. The stream frequency values of the sub-watersheds are well relating with drainage density indicating that number of streams increase with respect to increase in drainage density showing a positive correlation.

Form Factor (Rf)

The form factor 'Rf' points out the shape or outline form of a drainage basin capable of being understood and affects stream discharge behaviours. The ratio of the basin area to the square of basin length is called the Form factor (Horton, 1932). Smaller the values of 'Rf' more elongated will be the basin/watershed. The values of Form factor in the study area ranges from 0.27 to 2.57. Thus most of the sub-watersheds are more or less elongated in shape indicating lower peak flow for longer duration.

Circularity Ratio (Rc)

The circularity ratio 'Rc' is a shape measured depending on stream flow in the sub basin (Miller, 1953). The circularity ratio is influenced by the length and frequency of stream, geological structures, land use/land cover, climate, relief and slope of the basin. The 'Rc' values for the sub-watersheds varies from 0.15 to 0.37 indicating that all the sub-watersheds are of less circular in shape, low to moderate relief and a few structurally controlled drainage system.

Elongation Ratio (Re)

It is the ratio between the diameter of the circle of the same area as the drainage basin and the maximum length of the basin. A circular basin is more efficient in run-off discharge than an elongated basin (Singh, 1967). The value of elongation ratio (Re) generally varies from 0.6 to 1.0 associated with a wide variety of climate and geology. Values close to 1.0 are typical of regions of very low relief, whereas that of 0.6 to 0.8 are associated with high relief and steep ground slope (Strahler, 1964). 'Re' values in the present sub-watersheds varies from 0.6 to 1.7.The sub-watersheds SW9 (1.62), SW10 (1.79) and SW11 (1.62) have higher 'Re' value indicating high infiltration rate and low runoff and rest of the sub-watersheds are susceptible to erosion.

Texture Ratio (Rt)

Texture ratio is an expression of the relative channel spacing in fluvial dissected terrain. It depends on a number of natural factors such as climate, rainfall, vegetation, rock and soil type, infiltration capacity, relief and stage of development of a basin (Smith, 1950). Horton recognized infiltration capacity as the single important factor which influences drainage texture (Rt) and considered the drainage texture to include drainage density and stream frequency. Smith (1950) has classified drainage density into five different texture i.e., very coarse (< 2), Coarse (2- 4), moderate (4- 6), fine (6- 8) and very fine (> 8). In the present study area the 'Rt' value range from 0.99 to 2.14 indicating that all the sub-watersheds fall under coarse to very coarse category of texture with plain and lower degree of slope.

PRIORITIZATION OF SUB-WATERSHEDS

The sub-watershed prioritization for the present study is based on the morphometric parameters like drainage density, stream frequency, bifurcation ratio, circularity ratio, elongation ratio and form factor as they have direct relation with erosion, infiltration etc. Thus 14 sub watersheds have been delineated.

Table 1: Morphometric Parameters

	SW1	SW2	SW3	SW4	SW5	SW6	SW7	SW8	SW9	SW10	SW11	SW12	SW13	SW14
Area (Sq.km)	45.91	69.82	63.77	32.47	61.01	34.47	37.34	42.07	32.15	30.55	38.98	30.96	27.17	22.33
Perimeter (Km)	47.81	51.62	46.65	43.64	51.62	36.52	45.06	38.08	41.54	41.16	44.06	38.7	46.33	32.63
Basin Length (Km)	8.99	12.17	9.71	10.44	9.8	8.7	5.08	7.06	3.95	3.42	4.34	6.04	4.75	5.56
Bifurcation Ratio	3.8	4.5	4.2	6.2	9.7	3.4	6.7	4.1	3.8	3.2	3.6	3.5	6.5	3.3
Drainage Density(km/km^2)	1.4	1.46	1.36	1.42	1.41	1.5	1.45	1.43	1.54	1.38	1.48	1.49	1.32	1.51
Stream Frequency	1.55	1.54	1.56	1.5	1.35	1.26	1.4	1.72	1.8	1.59	1.64	1.58	1.82	1.88
Form Factor	0.55	0.47	0.67	0.27	0.63	0.42	1.4	0.8	2.06	2.52	2.07	0.84	1.1	0.75
Circularity Ratio	0.25	0.33	0.37	0.2	0.29	0.31	0.22	0.35	0.23	0.22	0.24	0.26	0.15	0.28
Elongation Ratio	0.84	0.77	0.93	0.6	0.9	0.74	1.34	1.01	1.62	1.79	1.62	1.04	1.19	0.98
Texture Ratio	1.46	2.09	2.14	1.05	1.58	1.12	1.13	1.81	1.39	1.14	1.45	1.26	0.99	1.34

Table 2: Sub-Watershed Prioritization Based on Morphometric Analysis

SW	Bifurcation Ratio	Drainage Density (km/km^2)	Stream Frequency	Form Factor	Circularity Ratio	Elongation Ratio	Compactness Coefficient	Texture Ratio	Compound Parameter	Final Priority
sw1	8	11	9	4	6	4	9	5	7	5
sw2	5	6	10	3	11	3	3	2	5.38	1
sw3	6	13	8	6	13	6	1	1	6.75	4
sw4	4	9	11	1	2	1	13	13	6.75	4
sw5	1	10	13	5	9	5	5	4	6.5	3
sw6	11	3	14	2	10	2	4	12	7.25	7
sw7	2	7	12	11	3	11	11	11	8.5	10
sw8	7	8	4	8	12	8	2	3	6.5	3
sw9	8	1	3	12	4	12	10	7	7.13	6
sw10	13	12	6	14	3	13	12	10	10.38	11
sw11	9	5	5	13	5	12	8	6	7.88	9
sw12	10	4	7	9	7	9	7	9	7.75	8
sw13	3	14	2	10	1	10	14	14	8.5	10
sw14	12	2	1	7	8	7	6	8	6.38	2

The shape parameters like circularity ratio, elongation ratio and form factor have inverse relation with erosion (Nooka Ratnam et. al., 2005). The compound parameter values of all sub-watersheds were calculated and prioritized (Map 3a). Keeping the Compound parameter as base, the ranking has been assigned. Thus highest ranking is given for higher values of linear parameters and lowest value for shape parameters. The priority values are given in Table 2. The Sub-watersheds were categorized into very high (0-3), High (3-6), medium (6-9) and low (9-12). Sub-watersheds SW2 and SW14 receive a very high priority with compound value of 5.38 and 6.38 respectively. SW1 (7), SW3 (6.75),

SW4 (6.75), SW5 (6.5) and SW8 (7.13) have high priority. SW6 (7.25), SW9 (7.13) and SW12 (7.75) have medium priority SW7 (8.50), SW10 (10.38), SW11 (7.88) and SW13 (8.50) have lowest priority. Hence higher priority sub-watersheds are potential zones for watershed management and they are SW2, SW14, SW1, SW3, SW4, SW5 and SW8 respectively.

LAND USE / LAND COVER ANALYSIS

Based on visual interpretation keys, identification and delineation, different land use / land cover features have been carried out (Map 2). Land use/land cover categories in the study area includes cultivated land (crop land, fallow and agricultural plantations), open scrub, wastelands (land without scrub, salt affected land, barren rock/stony waste) and water bodies (rivers, streams, tanks). Land use /land cover map has been prepared using IRS - 1C, LISS III (FCC). The details of land use /land cover categories are presented in Table 3.

Cultivated Land

The land which is used for production of food and commercial crops is termed as cultivated land. Cultivated land includes crop land, fallow and agricultural plantations. 93% of cultivated area is noticed in SW3 and minimum of 19.9% is observed in SW14.The Sub-watersheds with lesser cultivated area is given higher priority than that of the higher cultivated area.

Scrub Land

It is the land with lesser vegetative cover and waste land which result out of both biotic and abiotic influences. Scrubby land, includes stunted trees, bushes and shrubs. The scrub land was identified and delineated keeping the toposheets as reference along with the visual interpretation keys. In the study area scrubby land is confined to south and south- eastern parts. Low ranking is assigned for the area covered with higher scrub land and vice versa. About 18% of scrub land is observed in SW5 which is maximum.

Wasteland

Wasteland can be defined as the land which is currently unfit for use. It is a degraded land where the land is not managed properly for soil and water resources. The study reveals the presence of few patches of waste land in the study area. Wasteland includes salt affected area, stony waste, prosofis juliflora, etc. The maximum area of 4.85% of wasteland is observed in SW11. Sub-watersheds with higher percent of wasteland were given higher priority as the land and water resources are to be managed and sub-watersheds with lesser area of wastelands are ranked low.

Table 3: Land Use /Land Cover Analysis of Sub-Watersheds

Lu/Lc Category	Area (Km^2)	Area (%)	Area (Km^2)	Area (%)	Area (Km^2)	Area (%)
	SW1		**SW2**		**SW3**	
Cultivated land	40.89	91.05	52.71	75.49	59.5	93.3
Wasteland	1.69	3.76	1.8	2.58	0.57	0.89
Water bodies	2.29	5.1	2.93	4.2	2.09	3.28
Built up area	0.04	0.09	0.21	0.3	0.17	0.27
Open forest			0.99	1.42	0.26	0.41
Scruby land			11.18	16.01	1.18	1.85
	SW4		**SW5**		**SW6**	
Cultivated land	24.41	80.11	45	74.1	29.49	90.82
Wasteland	0.24	0.79	1.23	2.03	0.79	2.43
Scruby land	4.25	13.95	10.97	18.06		
Water bodies	1.55	5.09	1.18	1.94	1.99	6.13

Table 3: Contd.,

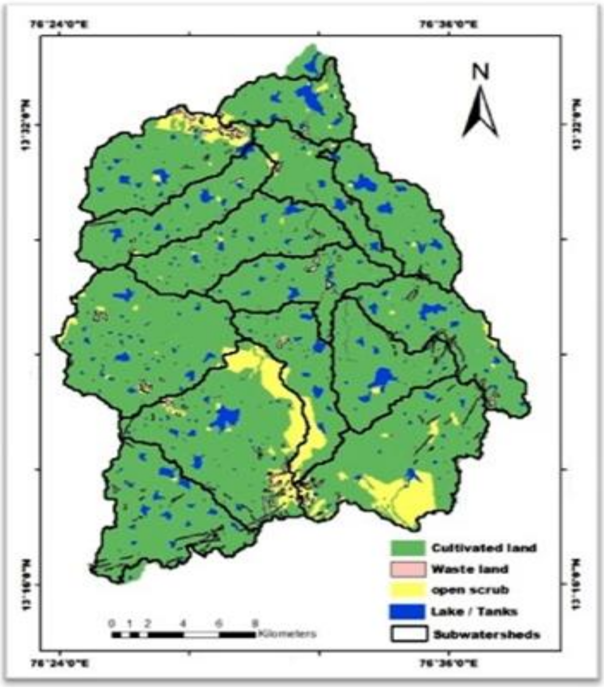
Built up area	0.02	0.07	0.11	0.18	0.2	0.62
Open forest			2.24	3.69		
	SW7		**SW8**		**SW9**	
Cultivated land	32.43	89.22	30.64	76.45	28.95	90.05
Wasteland	1.51	4.15	2.01	5.01	0.99	3.08
Water body	1.82	5.01	1.89	4.72	1.71	5.32
Built up	0.59	1.62	0.16	0.4	0.06	0.19
Scruby land			4.79	11.95	0.44	1.37
Open forest			0.59	1.47		
	SW10		**SW11**		**SW12**	
Cultivated land	26.78	90.63	36.43	93.46	27.45	88.66
Wasteland	1.43	4.84	0.77	1.98	0.97	3.13
Water bodies	1.32	4.47	1.61	4.13	2.44	7.88
Built up area	0.02	0.07	0.17	0.44	0.1	0.32
	SW13		**SW14**			
Cultivated land	22.3	88.6	19.19	85.94		
Wasteland	1.16	4.61	0.24	1.07		
Scruby land	0.48	1.91	0.51	2.28		
Waterbodies	1.09	4.33	2.1	9.4		
Built up area	0.14	0.56	0.29	1.3		

PRIORITIZATION OF SUB-WATERSHEDS

Land use / land cover based prioritization takes cultivated land, wasteland and scrub land into account. Generally high priority is to be given for the areas which have less vegetative cover, low cultivated area and highest wasteland. Whereas low ranking/priority is assigned to the sub-watersheds covering larger cultivated area with thick vegetation and lesser wasteland cover. The compound parameter values of all sub-watersheds were calculated and prioritized. Keeping the Compound parameter as base, the ranking has been assigned (Table 4).

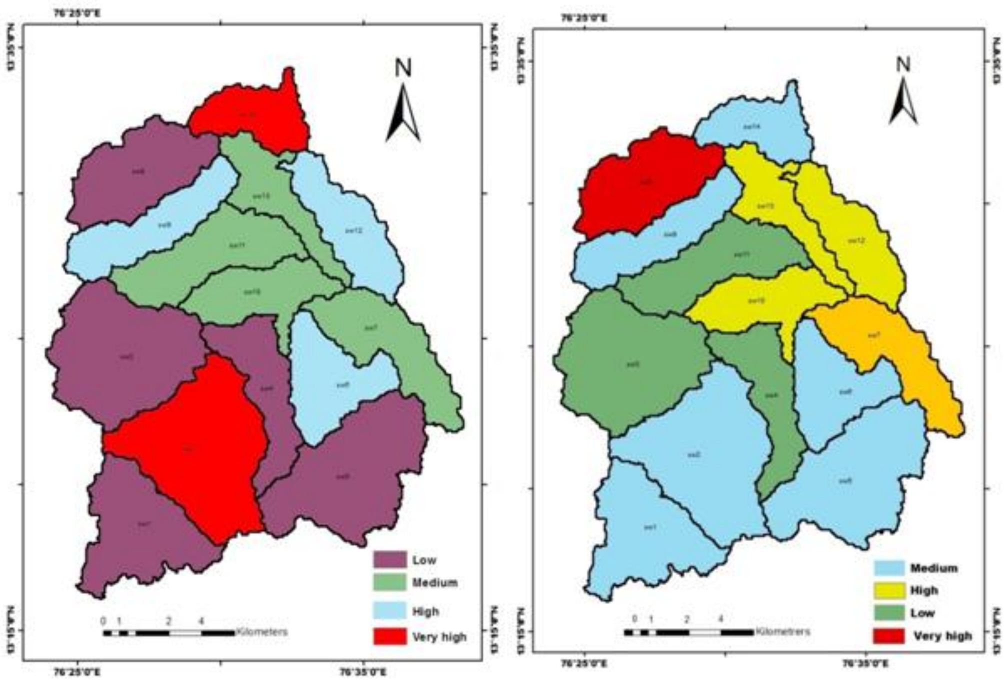
Table 4: Sub-Watershed Prioritization from Land Use / Land Cover Analysis

	Cultivated Land (%)	Waste Land (%)	Scruby Land (%)	Water Body (%)	Compound Value	Priority
SW1	91.14	3.76	0	5.1	6.00	Medium
SW2	75.49	2.58	17.73	4.2	6.00	Medium
SW3	93.3	0.89	2.53	3.28	10.00	Low
SW4	80.11	0.79	14.01	5.09	8.33	Low
SW5	74.1	2.03	21.93	1.94	6.66	Medium
SW6	90.82	2.43	0.62	6.13	7.00	Medium
SW7	89.22	4.15	1.62	5.01	4.33	High
SW8	76.45	5.01	13.82	4.72	3.33	Very High
SW9	90.05	3.08	1.55	5.32	6.00	Medium
SW10	90.63	4.84	0.06	4.47	4.33	High
SW11	93.46	1.98	0.43	4.13	8.66	Low
SW12	88.66	3.13	0.33	7.88	4.66	High
SW13	55.6	4.61	35.46	4.33	4.00	High
SW14	85.94	1.07	3.59	9.4	7.33	Medium



Map 2: Land Use /Land Cover

Sub-watersheds were categorized (Map 3b) into very high (2-4), High (4-6), medium (6-8) and low (8-10). Sub-watershed SW8 receives a very high priority with compound value of 3.33. SW7 (4.33), SW10 (4.33), SW12 (4.66) and SW13 (4) have high priority. SW1 (6), SW2 (6), SW5 (7), SW6 (6.66), SW9 (6) and SW14 (7.33) have medium priority. SW3 (10), SW4 (8.33) and SW11 (8.66) have lowest priority. Higher priority sub-watersheds are potential zones of watershed management Viz., SW8, SW7, SW10, SW12 and SW13. The results of both the morphometric and land use / land cover analysis were compared to find the common sub-watersheds of common priority. It was noticed that sub-watersheds SW6, SW9 and SW11 being the common sub-watersheds with medium priority. The rest of the sub-watersheds vary from one another with little correlation in their priority.



(a) (b)

Map 3: Priority of Sub-Watersheds (a) Morphometry and (b) Land Use/Land Cover Analysis

CONCLUSIONS

Application of Remote Sensing and GIS technique in morphometric and land use/land cover analysis have paved way for efficient planning and management of sub-watersheds considering their priority for natural resources Viz., soil and water resources. The present study reveals that sub-watersheds SW2 and SW14 receives a very high priority based on morphometric analysis and sub-watershed SW8 ranked under very high category based on land use/land cover analysis. It is observed that upon integrating both the morphometric and land use/ land cover thematic layers three sub-watersheds SW6, SW9 and SW11 are found to receive common priority by both the approaches and remaining sub-watersheds show little correlation difference. Thus integrated approach of morphometric and land use/land cover based analysis with the application of remote sensing and GIS helped not only in prioritizing the sub-watersheds but also for planning and decision making for sustainable sub-watershed development and management.

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